Correspondence.

Mr. Burns.

Mr. T. F. Burns observed, with reference to the Paper by Messrs. Bartlett and Cadwell, that the decision to build the entire jetty in cofferdam appeared to be difficult to justify, both from the point of view of ease of construction and from that of cost. As only 20 per cent. of the whole length was occupied by the intakes, it seemed unwise to employ such an expensive method for the remaining 80 per cent.; the cost per square foot of deck-surface was £7·4, and, even after making some allowance for the cost of the intakes, that figure would not appear to compare favourably with that for other jetties providing similar facilities. He had in mind a recently-constructed large jetty on the Thames providing for heavier loads than the Battersea jetty, the foundations of which were carried to a considerably greater depth; the cost was, however, about £3·8 per square foot. The stresses used in the concrete and steel were not given, but from the particulars stated it would appear that the maximum load carried by the piers was about 250 tons, which resulted in a direct stress of 350 lbs. per square inch; that seemed to be an extraordinarily light stress for a reasonably good concrete. It would be interesting to know what maximum stresses had been assumed in the design.

The horizontal forces acting on a jetty during the berthing of ships were always a matter of considerable speculation, but in the case under consideration Messrs. Bartlett and Cadwell seemed to have taken very severe conditions when they designed for a retarding force sufficient for a vessel of 2,000 tons deadweight approaching at a rate of 2·2 feet per second and being brought to rest in a length of 12 inches. He was a little puzzled by the 12 inches, as the fender-springs provided had a deflection of only $1\frac{3}{4}$ inch and the very rigid form of jetty precluded the structure from deflecting a measurable distance. Further, a very rough calculation showed that the kinetic energy to be absorbed from the impact of the ship would be in the neighbourhood of 1,800 inch-tons, whilst each set of fender-springs was capable of only 70 inch-tons of work. Perhaps the Authors would kindly amplify the information given on that matter.

Mr. Markwick.

Mr. A. H. D. Markwick observed that the general layout at Battersea resembled closely that of Barton power-station, which had

Mr. Markwick. been described before The Institution in a Paper[1] by the late Mr. H. N. Allott and Dr. S. L. Pearce, MM. Inst. C.E. In the design of the superstructure at Battersea, however, Messrs. Berry and Dean had incorporated many new features, which he thought deserved close study. The main stanchions were built up from plates and angles only, in place of beam- or channel-sections and plates. That construction had enabled the crane-girders to be carried directly from the main stanchions, and he observed from *Figs. 6* (p. 51) that in the turbine-house it had been possible to do that without any increase in the cross-sectional area of the columns. Another innovation was the use of fibre-board as heat-insulation between the asphalt and the concrete roof-slab. He hoped the Authors of both Papers would be able to confirm that by that means condensation, which sometimes occurred with that type of roof, had been eliminated.

Dunston appeared to be typical of the power-stations designed by Mr. Anderson's firm. Some of the characteristic features were that the switch-house and control-room were placed right away from the main buildings, that the boiler-houses were at right angles to the turbine-house, that outdoor transformers were used, and that the circulating-water ducts were at high level. The pump-house at Dunston was very similar to that at Barking, which had been described by Mr. James Williamson.[2] At Dunston, however, walls and floor had been considerably thickened, and the dead weight of the structure more than balanced the upward flotation. Possibly it had been felt that in view of the nature of the ground it would be unwise to rely in any way upon the earth filling. Mr. Markwick also noticed that in place of the stop-logs used at Barking, all screen- and suction-chambers at Dunston could be isolated for unwatering by means of penstocks. That provision would, he thought, be appreciated by those responsible for the operation of the station.

Mr. Nachshen. Mr. MAURICE NACHSHEN understood that in stations like Battersea great importance was placed on obtaining siphonic flow of the circulating-water at all states of the tide. At Battersea the lowest recorded tide-level was stated to be —8·75 O.D. The level of the tops of the exit-pipes from the condensers was not given, but, judging from the level of the turbine-floor, it would appear to be about + 18 O.D. or about 27 feet above lowest tide-level; he thought that that figure was rather more than was usually allowed. It would be of interest to know whether the pumps had been designed

[1] "The Barton Power-Station of the Manchester Corporation, and the Transmission System in Connection therewith." Minutes of Proceedings Inst. C.E., vol. ccxviii (1923–24), p. 325.

[2] "Jetty and Pump-House Works at Barking Power-Station." Minutes of Proceedings Inst. C.E., vol. 226 (1927–28), p. 135.

for overcoming anything more than friction, and, if not, whether any difficulties had arisen at low tide on that account. Mr. Nachshen

The foundation-design was unusual in having in the same building both piled foundations and foundations carried directly on the clay. It appeared to him that piled foundations would have been more economical in the case of all the interior foundations, and also that the work would have been expedited if the deep open excavations had been avoided. It would be of interest to know what factors had led to the use of the two types of foundations, and whether any differential settlement had been noticed as a result of it. With regard to the piles used, it would add to the value of Messrs. Berry's and Dean's Paper if the weight and type of hammer used and the specified set were given, and also any information as to whether any test-loads had been applied, and their results. The figures given on p. 44 for the weights of gravel and soil were not quite clear. Presumably where 65 lbs. per cubic foot was used as the weight of material below water, the water-pressure was added to the lateral pressure from the material alone, but he did not understand why a weight as high as 125 lbs. per cubic foot should be expected anywhere for material below water, in addition to water-pressure.

With regard to the circulating-water intake and outlet at the jetty, it would appear that no provision was made for definitely preventing the warm water from the outlet from entering the intake, which was only about 200 feet away and directly downstream from it. From the drawings that appeared quite possible at ebb tide, and if it occurred it would adversely affect the efficiency of the station. Had any tests been made to show whether or not that was occurring? It was not clear why it had been necessary to enclose the whole of the jetty with coarse screens instead of only the area round each intake. Some information as to the method of removing and handling those screens would be of interest. Had it been found that silting was taking place under the jetty? That might be expected as a result of the obstruction of the river-flow by the screens and the close bracing of the jetty, as well as by the dredging of the area under the jetty to several feet below its original level. The further pocket formed by the intake-chamber itself might be expected to collect silt when the flow of circulating water was small, which silt might be carried into the condensers when the flow increased. Had any facilities been provided for removing silt from under the jetty?

The steel sluice-gates used were admirable in their simplicity, and it would be interesting to know to what degree they were tight, and also the means used for lowering and lifting them.

Mr. E. G. Walker observed that it was clear from Mr. Anderson's descriptions that the foundation-problems at Dunston were very Mr. Walker.

Mr. Walker. difficult, and therefore the records of the pile-driving operations were of considerable value. It was to be regretted, therefore, that so little information was given as to the methods used in arriving at the bearing power of the piles in the various parts of the work. In the Appendixes to the Paper the records of the driving of two test-piles were given, but the Author stopped short at the point where his records began to be of value, and merely stated on p. 8 that "From this information the safe load per pile at various depths was calculated." The subject of the calculation of the safe load on piles had always been one of considerable controversy, and it was only in comparatively recent years that the subject had been examined on anything other than an empirical basis. It would, therefore, be of considerable value to have on record particulars of how Mr. Anderson had arrived at his results. The reference which he made on p. 9 to the increased resistance to the driving of piles after large numbers had been driven in the surrounding area showed the difficulty of assessing with any degree of reliability the maximum safe load which could be applied to any individual pile. If, therefore, the load had been estimated upon the result of two driving tests, it had presumably been necessary to make a number of modifying assumptions if the full bearing value of all the piling was utilized. Furthermore, it was a common experience in pile-driving in silty material to find that a pile which had required very little effort to drive would, after being in position for a comparatively short period, acquire very greatly increased resistance. In the test-result which the Author gave there seemed to be no attempt to ascertain whether any time-effect of that sort had existed. If an attempt had been made to withdraw the test-pile some time after it had been driven, it was possible that the results might have differed very considerably from those obtained in the driving tests.

On p. 17 the Author gave figures for the slopes of the coal-storage bunkers. It would be interesting to learn whether the provision of the comparatively steep slope of 70 degrees for the pulverized-coal bunker, as compared with that of 53 degrees for the bunkers in the stoker-fired boiler-house, had effected any definite improvement in the flow of the coal, and had freed the installation from the trouble of "hanging-up" of the coal in the bunker. In Mr. Walker's experience, pulverized coal, even with a comparatively small percentage of moisture, would frequently stick on the sides even of vertical bins. Unless it was possible to ensure a very low moisture-content, there would always be a certain amount of "hanging-up," no matter what the steepness of the slope. At the same time there was no doubt that the steepest possible slope should always be used.

Mr. Anderson. Mr. ANDERSON, in reply, observed that, like the Discussion, most of the Correspondence on Dunston power-station dealt with the foundation-problems, pump-house, and circulating-water mains. Most of the criticisms had been dealt with in his reply to the Discussion, but perhaps some further particulars of the method of estimating the safe load on the piles might be of interest. Although by using the formula previously given (p. 108) a safe load per pile had been obtained in some instances considerably in excess of any load likely to be realized, in the light of previous experience on the site it was considered very unwise to use a design-load per pile of more than 30 tons, owing to the very poor nature of the alluvial strata below the stratum of ballast. He might even go so far as to say that the calculated safe load per pile was merely a guide to show that the pile had been driven sufficiently far into the ballast to a predetermined set, so as to ensure that sufficient resistance at the shoe had been obtained so that the pile would carry as a strut a safe load of 30 tons. **Mr. Anderson.**

Referring to the steep slope of the coal-storage bunkers in the pulverized-fuel-fired boiler-house, he wished to make it clear that those bunkers were not for storing pulverized fuel. They were to store dust and duff fuel, which was very small coal from colliery dry-cleaning plants, and low-grade fire coal, which were very much larger in size than pulverized coal. The fuel from the bunkers was passed through pulverizers situated at basement-floor level and was thence fired direct to the boilers. The steep slope of the bunker sides had been very satisfactory, and no troubles had been occasioned by "hanging-up."

The use of fibre-board as heat-insulation between the concrete roofing and the felt and asphalt surfacing had proved satisfactory. During the exceptionally cold winter of 1935–36 no troubles from condensation had been experienced.

Messrs. Berry, Dean, Bartlett, and Cadwell, in reply, observed that, among the many considerations which had influenced the general design of the coaling jetty, the factor which had decided the final choice was undoubtedly the arrangement of the circulating-water system, on which the efficiency of the station so largely depended. In the preliminary design of the river-works, the outlet-chamber was to be placed about 250 feet from the river-wall; that would have provided almost ideal conditions for the circulating-water system, and an independent coaling jetty on the lines suggested by Mr. T. F. Burns would have been possible. That arrangement had been objected to by the Port of London Authority, who feared possible obstruction to the river-channel during construction and a possible fouling of ships anchored when mooring or sluing. It had therefore been laid down that no works were to extend beyond the line of **Messrs. Berry, Dean, Bartlett, and Cadwell.**

Messrs. Berry, Dean, Bartlett, and Cadwell. the jetty. The discharge- and intake-chambers thus had to lie almost in line with the river stream, and the problem arose of preventing the warm discharge being carried to the intake-chamber. It had been decided that with a horizontal discharge, combined with a sufficient depth of water for dilution, the resulting increase in temperature of the intake-water would not be serious. That had proved to be the case; in fact, during a recent drought when the "up river" water fell to a minimum the vacuum in the condensers had not been seriously affected, even at slack low water. In order to provide deep water over the intake-chambers and generally under the jetty, a retaining-wall 15 feet high along the back row of jetty-piers was necessary to support the barge-berth between the jetty and wharf. That wall actually formed part of the jetty, and took the thrust from the horizontal and diagonal bracing. As so much of the submerged work, including the retaining-wall, outlet-chamber, screens, and intake-chambers, lay within the area to be covered by the jetty and the dolphins, the Engineers decided to construct the complete river-works, including the jetty itself, in cofferdam.

It was clear that in view of those special circumstances under which the Battersea jetty was designed, no useful comparison could be made between the costs of the jetty and of other jetties recently constructed in the river, particularly if the comparison were to be made on the cost per square foot of deck area. A comparison could, however, be made on the basis of cost of river-works per kilowatt installed (including coaling jetty, circulating-water system, barge-berth, etc.). Assuming the present circulating-water system to be duplicated in the completed station of 500,000 kilowatts, the cost per kilowatt installed would be less than 16*s*., which figure compared favourably with those of other riverside stations. The original contract price for the jetty was considerably less than the actual cost given in the Paper. It had been intended to construct the jetty in four successive sections, but the loss of time due to a change of contractors after the first cofferdam had been completed made it imperative that the remaining sections should be carried out simultaneously, at an extra cost of approximately £30,000.

With regard to the stresses in the jetty concrete, the maximum load on the front columns was 306 tons and on the shore columns 358 tons, giving average stresses of 620 lbs. per square inch and 644 lbs. per square inch respectively. The deflection of $1\frac{3}{4}$ inch in the fender-springs mentioned by Mr. Burns did not represent the ultimate safe capacity of the springs. The number of springs assumed by Mr. Burns should be doubled. Although further elastic deflection was provided by the timber fender-piles, it was not the intention to provide in the fenders for the full impact-loading used in designing

Messrs. Berry, Dean, Bartlett, and Cadwell.

the jetty structure. The timber piles were designed to distribute the impact-loading to the fender-springs at the top and to the ground at the bottom. There was thus a length of nearly 50 feet of piles, which was capable of sustaining considerable deflection without rupture, and it was considered that, in the event of rupture, the crushing resistance of the timber would also materially assist in preventing serious damage to the reinforced-concrete structure.

In reply to Mr. Markwick, the fibre-board insulation had been effective, as elsewhere, in preventing internal condensation, but it was necessary to add that some difficulty had been experienced subsequently owing to movement of the asphalte above in hot weather, which had caused splitting and leakage.

With regard to Mr. Nachshen's question about silting under the jetty, no serious trouble had yet occurred, and none was now expected. When the jetty had been completed, in December, 1931, the steel sluice-gates had been placed in the intake-chamber, and remained in position until the tunnels were flooded, about 12 months later. It was then found that the intake-chamber had filled with silt to a considerable depth, but the silt had been successfully removed by means of compressed-air jetting from the gangways under the jetty. Some silt had accumulated under the ends of the jetty, where the flow of intake-water was negligible; that silt had not been removed, and had not increased in quantity during the last 2 or 3 years.

The steel sluice-gates with rope "sausage" seating had proved very successful in operation, and were perfectly watertight as soon as a head of 6 feet of water had been applied. The gates in the intake-chambers were handled by the jetty-cranes, and those in the screening-chamber and suction-chamber by the 7-ton yard-crane. The isolating sluice on shaft "B," which might be required in emergency, was permanently suspended from a steel frame having a quick-release brake-controlled lowering device and a hand-operated lifting gear. Siphonic flow in the circulating-water system was ensured at all states of the tide by means of connections to air-exhauster pumps at various points on the system, including the cover over shaft "A." The discharge-water fell therefore under siphonic conditions to shaft "B," in which the water was at river-level.

Experience at the other riverside stations of the London Power Company, where the coarse screens had been placed round the area covered by the intake, had shown that the velocity of water through the screens was capable of carrying large submerged articles, such as tarpaulins or sacks, against the screens, resulting in serious loss of head on the pumps. With that experience in view it was thought desirable to surround the complete jetty so that the velocity through the screens should be a minimum.

Messrs. Berry, Dean, Bartlett, and Cadwell.

Various types of steel sheet-piling and in-situ bearing piles had been used in the work, and tests had been made. The test results presented no special feature of interest.

The weight of 125 lbs. per cubic foot of material below water-level used in the design of the pump-chamber wall had been required by the London County Council to allow for incidental pressure which might be induced on the wall by foundations and other works likely to be constructed in the vicinity.